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(54) Pumping fluid through plural flow lines

(57) A pump 39 has an inlet and an outlet for transporting fluid therethrough. First 40, 26 and second 52 flow lines are selectively connectable to the pump inlet via a first valve 42. Third 44, 28 and fourth 49 flow lines are selectively connectable to the outlet via a second valve 46. The pump 39 can be used to selectively pump fluid through different flow paths. The pump 39 may be a peristaltic pump and the apparatus may be a single needle dialysis system, the needle 24 being connected to the first 40, 26 and third 44, 28 flow lines and the dialyzer connected to the second 52 and fourth 49 flow lines.

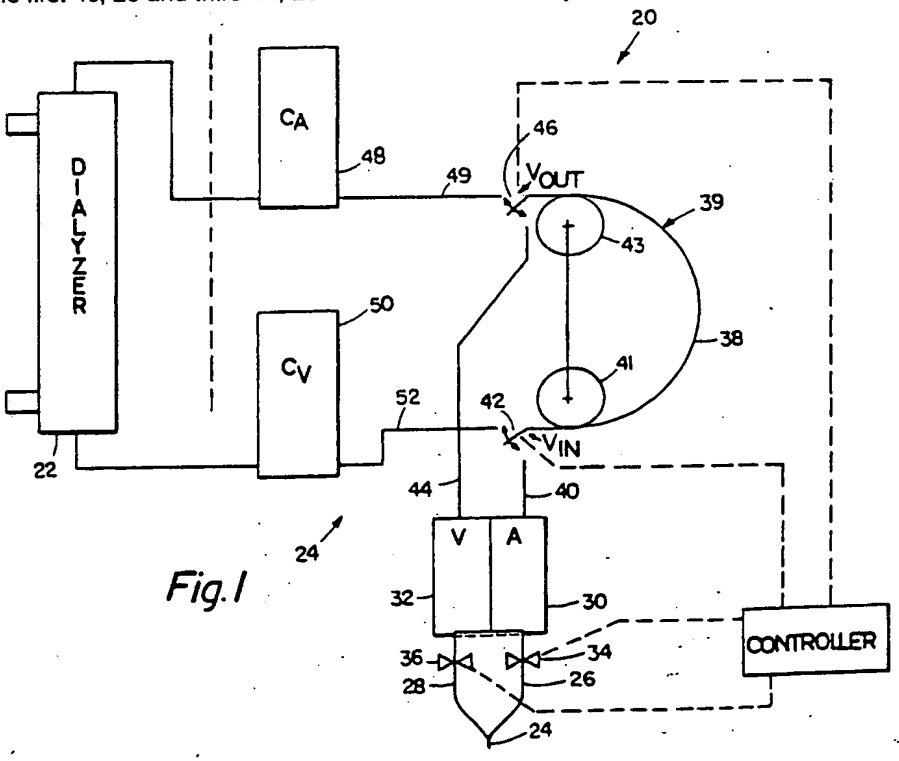

Fig.1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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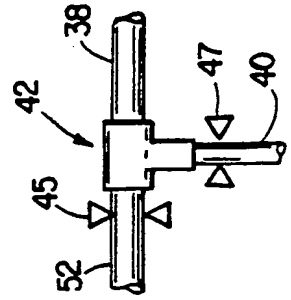

Fig.2

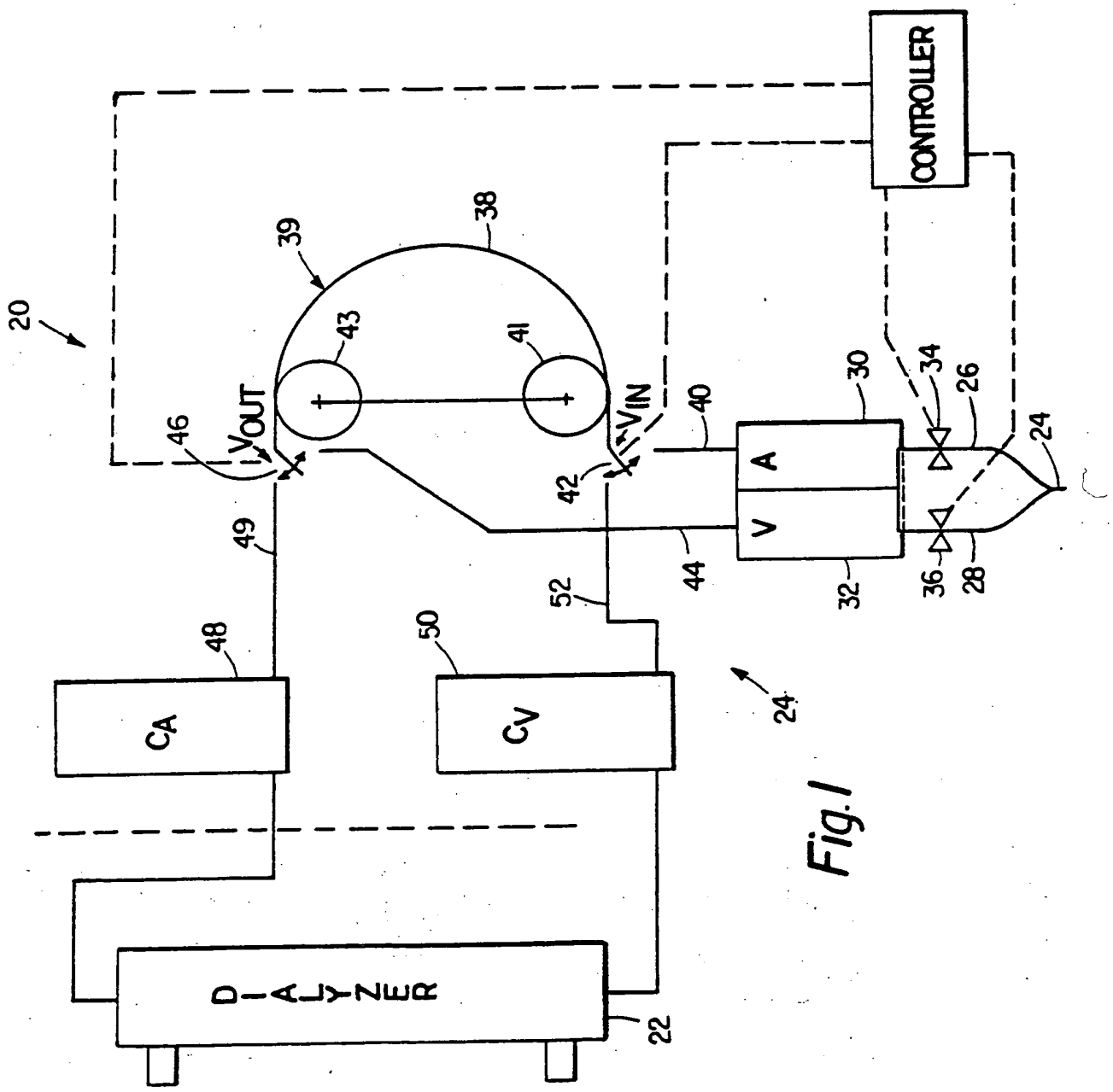

Fig.1

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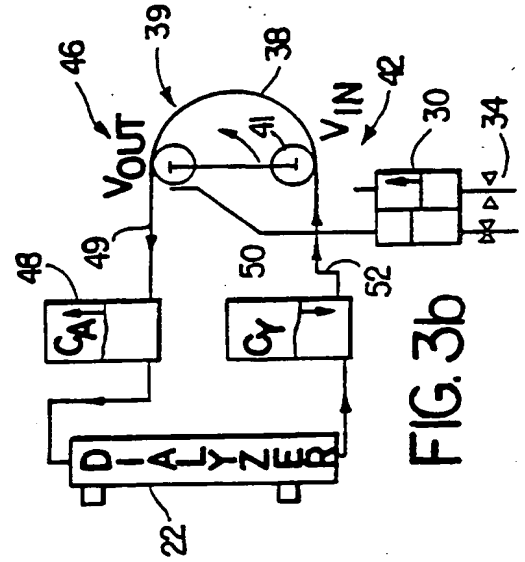

FIG. 3b

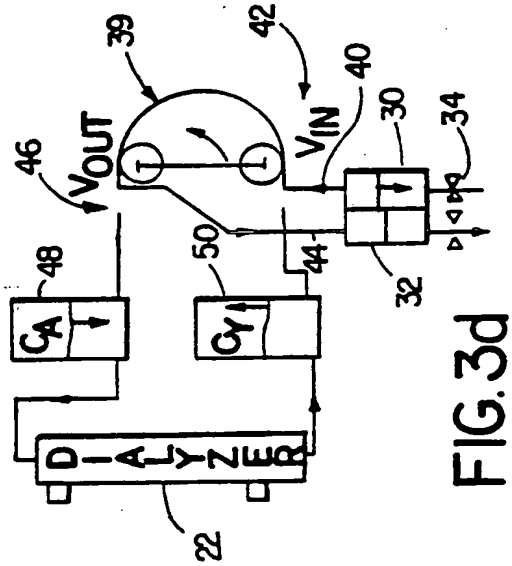

FIG. 3d

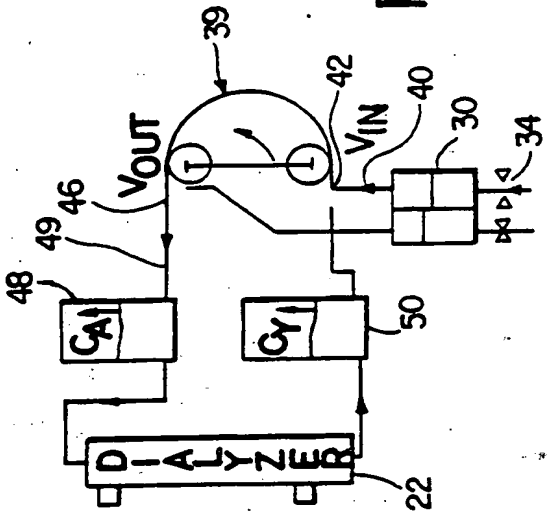

FIG. 3a

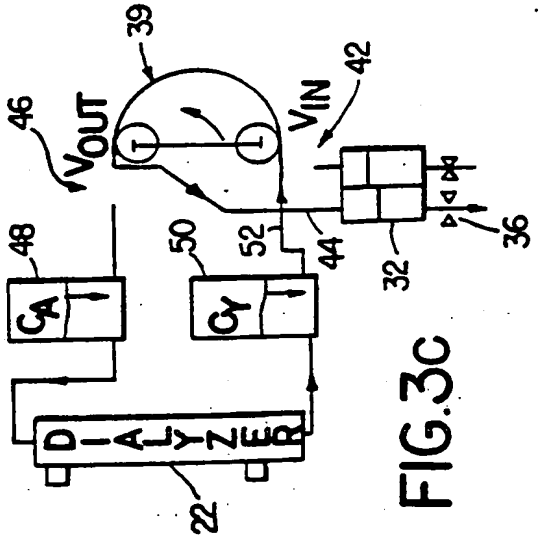

FIG. 3c

PUMPING FLUID THROUGH PLURAL FLOW LINES

The present invention relates to pumping fluid through plural flow lines, e.g., arterial and venous lines used in single needle dialysis.

Single venipuncture needles have been used to cyclically remove untreated blood from a patient and return treated blood to a patient, e.g., in conjunction with fluid flow transfer devices such as dialyzers connected to the needles via arterial and venous flow lines and drip chambers.

One or two pumps can be used, and the pumps and valves on the flow lines are controlled so as to provide flow of untreated blood from the patient and into the arterial line during an arterial phase and flow of treated blood through the venous line to the patient during a venous phase, e.g., as is described in Brose U.S. Patent No. 4,643,714. If two pumps are used, they are generally alternately operated so that only one is on at one time. If one pump is used, it is operated continuously, and the pressures vary widely during the arterial and venous phases.

We have now discovered that fluid pumping could be efficiently provided by a single pump in a system having plural flow lines by making first and second lines selectively connectable to the pump inlet by a first valve and third and fourth lines selectively connectable to the pump outlet by a second valve. The pump can thus be used at different times to pump fluid through different flow paths, e.g., through a path

including the first and third lines or a path including the second and fourth lines.

In accordance with a first aspect of the present invention, there is provided apparatus for pumping fluid through plural flow lines comprising: a pump having an inlet and an outlet for transporting said fluid therethrough, first and second flow lines that are selectively connectable to said pump inlet via a first valve, and third and fourth flow lines that are selectively connectable to said outlet via a second valve, whereby said pump can be used to selectively pump fluid through different flow paths.

The invention provides, in a second and alternative aspect thereof, a method of pumping fluid through plural flow lines comprising the steps of: providing a pump having an inlet and an outlet for transporting fluid therethrough, first and second flow lines that are selectively connectable to said pump inlet via a first valve, and third and fourth flow lines that are selectively connectable to said outlet via a second valve; switching said first valve to connect one of said first and second flow lines to said inlet and to disconnect the other; switching said second valve to connect one of said third and fourth flow lines to said outlet and to disconnect the other; and pumping fluid through said pump.

In preferred arrangements: the pump is a peristaltic pump having a pump header; the fluid flow system in which the system is used is a single needle dialysis system; the system utilizes expansion chambers and drip chambers; and the system has various phases including a draw phase in which blood is drawn from the patient through the first line and pumped through the fourth line to the dialyzer, a first transitional phase in which the untreated blood in the pump header is

pumped into the fourth line and replaced by treated blood from the dialyzer through the second line, a return phase in which treated blood is pumped from the dialyzer through the second line and returned through the third line to the patient, and a second transitional phase in which treated blood in the pump header is pumped into the third line and is replaced by untreated blood from the first line. The first transitional phase avoids returning untreated blood in the header to the patient at the beginning of the return phase. The second transitional phase avoids processing blood twice, promoting efficiency. In practical embodiments there is an advantage over some present single-pump systems in avoiding large pressure swings and over some present double-pump systems in continuous pump operation, promoting pump motor life.

Other advantages and features will be apparent from the following description of a preferred embodiment thereof, by way of reference to the drawings, in which:-

Fig. 1 is a diagrammatic representation of an embodiment of pumping system according to the invention;

Fig. 2 is a diagram of a clamp valve used in the Fig. 1 system; and

Figs. 3A-3D are diagrammatic representations showing the flow paths of the Fig. 1 system during different phases.

Referring to Fig. 1, there is shown single needle dialysis apparatus 20 for removing untreated blood from a patient (not shown), treating the blood in hollow fiber dialyzer 22 (a "fluid flow transfer device") and returning the blood to the patient. Apparatus 20 is connected to the patient via needle 24 and arterial and venous lines 26, 28. Arterial and venous lines 26, 28 are connected to patient arterial and venous drip chambers 30, 32 and controlled with pinch valves 34, 36.

Arterial drip chamber 30 is connected to the inlet end of pump header 38 of peristaltic pump 39 via flow line 40 and clamp valve 42 (the "first valve"). Pump 39 has rollers 41, 43, which compress header 38. The structure of valve 42 is shown in Fig. 2; it includes two pinch clamps 45, 47 that are alternately opened and closed so that only one of line 40 (comprising with line 26 the "first line") or line 52 is connected to the inlet of pump header 38 at once. Venous drip chamber 32 is connected to the outlet end of pump header 38 via flow line 44 (comprising with line 28 the "third line"), and clamp valve 46 (the "second valve"), having the same structure as clamp valve 42. The inlet of arterial expansion chamber 48 is connected

via fluid line 49 (the "fourth line") to clamp valve 46. The outlet of arterial expansion chamber 48 is connected to dialyzer 22. The outlet of dialyzer 22 is connected to venous expansion chamber 50. The outlet of expansion chamber 50 is connected via fluid line 52 to clamp valve 42. Controller 60 is electrically connected to control valves 34, 36, 42, 46. Pinch valves 34, 36 are referred to as "fifth and sixth pinch valves". The pinch valves that are used are actuated by solenoids and returned by springs.

In operation, single needle apparatus 20 is repeatedly operated through four functional phases: the draw phase (Fig. 3A), the first transitional phase (Fig. 3B), the return phase (Fig. 3C), and the second transitional phase (Fig. 3D). Throughout these phases, clamp valves 42, 46 alternately clamp one of the two lines that they each respectively connect to pump header 38, thereby providing flow through the other flow line to or from pump header 38. E.g., clamp valve 42 alternately clamps line 40 with pinch clamp 47 and line 52 with pinch clamp 45.

Referring to Fig. 3a, in the draw phase, pump 39 is connected to line 40 via valve 42 and to line 49 via valve 46, and pinch valve 34 is opened to allow unprocessed blood to flow from the patient and into the hydraulic circuit, including flow of some of the blood through dialyzer 22, where it is treated. During this phase, the volumes in expansion chambers 48, 50 increase, and pressure downstream of pump 39 increases.

Referring to Fig. 3B, in the first transitional phase, which lasts for one-half revolution of pump 39, clamp valves 42, 46 connect pump header 38 to lines 52, 49, respectively. Unprocessed blood is moved from pump

header 38 to expansion chamber 48 while processed blood from chamber 50 enters header 38. In addition, pinch valve 34 remains open to allow pressure in drip chamber 30 to stabilize, increasing the volume of unprocessed blood in chamber 30. The first transitional phase avoids returning the untreated blood that is within the pump header to the patient in the beginning of the return phase.

Referring to Fig. 3C, in the return phase, pump 39 is connected to lines 44, 52, and pinch valve 36 is opened. Treated blood is pumped from dialyzer 22 and returned to the patient. During this phase, the volumes of expansion chambers 48, 50 decrease, as do the pressures in them. Because blood can be returned to a patient faster than it can be removed from a patient, pump 39 may be operated faster in the return phase than in the draw phase, thereby speeding up flow of blood through the system.

Referring to Fig. 3D, in the second transitional phase, clamp valves 42, 46 connect pump 39 to lines 40, 44, and the processed blood in header 38 is replaced with unprocessed blood from chamber 30. The processed blood is returned to the patient, and the volume of blood in chamber 30 is decreased. The second transitional phase avoids treating blood in the dialyzer twice, thereby improving efficiency.

Because the present system utilizes a single pump instead of two pumps, it may be operated continuously; i.e. the pump motor does not have to be started and stopped (as with at least some two-pump designs), thus prolonging the useful life of the pump motor. The use of one pump also saves the expense of providing more than one pump per fluid flow apparatus. The present system improves over some existing

single-pump systems, because it has reduced pressure changes, and higher flowrates can be achieved at larger stroke volumes. Also, in the present system the pump can be easily operated at different speeds in different phases, permitting one to take advantage of the fact that it is possible to return blood to a patient faster than the blood is drawn from the patient.

Other embodiments are feasible. E.g., arterial and venous lines 26, 28 may be connected directly to valves 42 and 46, respectively, and the second transitional phase can be omitted. Thus the processed blood which is in pump header 38 at the end of the return phase is processed by dialyzer 22 a second time.

CLAIMS:

1. Apparatus for pumping fluid through plural flow lines comprising: a pump having an inlet and an outlet for transporting said fluid therethrough, first and second flow lines that are selectively connectable to said pump inlet via a first valve, and third and fourth flow lines that are selectively connectable to said outlet via a second valve, whereby said pump can be used to selectively pump fluid through different flow paths.

2. Apparatus according to Claim 1, wherein said pump is a peristaltic pump having a roller adapted to compress a header operatively containing said fluid to move said fluid through said header, said header having said inlet and said outlet.

3. Apparatus according to Claims 1 or 2, wherein said apparatus is a single needle dialysis system, and further comprises a needle connected to said first and said third flow lines, and a dialyzer connected to said second and fourth flow lines.

4. Apparatus according to Claim 4, further comprising a first expansion chamber connected along said fourth flow line between said second valve and said dialyzer, and a second expansion chamber connected along said second flow line between said first valve and said dialyzer.

5. Apparatus according to any preceding claim, wherein said first valve comprises a first pinch valve connected selectively to stop the flow of fluid through said first flow line and a second pinch valve connected selectively to stop the flow of fluid through said second flow line, and wherein said second valve comprises a third pinch valve connected selectively to stop the flow of fluid through said third flow line and a fourth pinch valve connected selectively to stop the flow of fluid

through said fourth flow line.

6. Apparatus according to Claim 5, further comprising fifth and sixth pinch valves connected selectively to stop the flow of fluid through said first and third flow lines, respectively.

7. Apparatus according to any preceding claim, further comprising a first drip chamber connected along said first flow line, and a second drip chamber connected along second flow line.

8. Apparatus according to any preceding claim, further comprising a controller electrically connected to said first and second valves, said controller being adapted to control said first valve operatively to connect one of said first and second flow lines to said pump inlet at one time and to control said second valve operatively to connect one of said third and fourth flow lines to said pump outlet at one time.

9. A method of pumping fluid through plural flow lines comprising the steps of: providing a pump having an inlet and an outlet for transporting fluid therethrough, first and second flow lines that are selectively connectable to said pump inlet via a first valve, and third and fourth flow lines that are selectively connectable to said outlet via a second valve; switching said first valve to connect one of said first and second flow lines to said inlet and to disconnect the other; switching said second valve to connect one of said third and fourth flow lines to said outlet and to disconnect the other; and pumping fluid through said pump.

10. A method according to Claim 9, wherein said pumping step is performed continuously, and said switching steps result in a plurality of phases with different flow paths through said first, second, third

and fourth flow lines.

11. A method according to Claim 10, wherein said first line is connected to a source of untreated fluid, said third line is connected to a destination arranged to receive treated fluid, said second and fourth lines are connected to a fluid flow transfer device, and one of said plurality of phases is a draw phase in which said first line is connected to said inlet, said fourth line is connected to said outlet, and untreated fluid is pumped from said first line to said fourth line, thereby drawing untreated fluid from said source.

12. A method according to Claim 11, wherein one of said phases is a return phase in which said second line is connected to said inlet, said third line is connected to said outlet, and treated fluid is pumped from said second line to said third line, thereby passing treated fluid to said destination.

13. A method according to Claim 12, wherein one of said phases is a first transitional phase in which said second line is connected to said inlet, said fourth line is connected to said outlet, and untreated fluid in said pump is pumped to said fourth line and replaced by treated fluid in said second line.

14. A method according to Claim 13, in which first and second drip chambers are provided along said first and third flow lines, and wherein one of said phases is a second transitional phase in which said first flow line is connected to said inlet, said third flow line is connected to said outlet, and treated fluid in said pump is pumped to said third line and replaced by untreated fluid in said first line from said first drip chamber.

15. A method according to any of Claims 1 to 14, in which a first expansion chamber is connected along said fourth flow line, and a second expansion chamber is

connected along said second flow line, and wherein said draw phase comprises increasing the volume in said first expansion chamber and said second expansion chamber.

16. A method according to both Claims 12 and 15, wherein said return phase comprises decreasing the volume in said first expansion chamber and said second expansion chamber.

17. A method according to Claims 13 and 15, wherein said first transitional phase comprises filling said first expansion chamber and emptying said second expansion chamber.

18. A method according to Claims 14 and 15, wherein said second transitional phase comprises emptying said first expansion chamber and filling said second expansion chamber.

19. A method according to Claim 11 or any claim appendant thereto, wherein said source comprises a supply of untreated blood which has been drawn from a patient, and said destination comprises means adapted for accepting blood for return to a patient.

20. For pumping fluid through plural flow lines, a method substantially as hereinbefore described with reference to the accompanying drawings.

21. Apparatus for pumping fluid through plural flow lines, substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

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